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Improving students' reflective thinking skills on environmental change through a deep learning approach integrated with creative problem-solving in Biology

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ABSTRACT

Reflective thinking is an essential skill for students to evaluate evidence, review their learning, and address environmental issues, particularly in biology. Conceptually, integrating Deep Learning and Creative Problem-Solving is seen as relevant for improving students' reflective thinking skills. Deep Learning provides direction for the formation of meaningful, conscious, and contextual understanding, while Creative Problem-Solving provides learning procedures that encourage students to identify problems, analyze information, develop alternative solutions, and evaluate decisions. This research investigated how Grade X students' reflective thinking evolved after applying Creative Problem Solving within a deep learning framework during environmental lessons. A quantitative pretest-posttest approach was employed with 108 students across three classes, collecting data from a 10-item essay test and a 20-item reflective thinking scale. Results indicated that combining deep learning and Creative Problem Solving significantly enhanced reflective thinking ($p < 0.05$). The R^2 values demonstrated positive effects: 22% in Research Class I, 12.2% in Class II, and 53% in Class III, with improvements in reacting, comparing, and contemplating. These findings imply that integrating deep learning with Creative Problem Solving can effectively boost reflective thinking in biology, especially regarding environmental issues.

INTRODUCTION

The development of science education requires that biology learning is not only oriented towards mastering concepts, but also towards students' ability to analyze, reflect, and use scientific knowledge to understand real-life problems. This demand is even more relevant when biology learning faces the issue of environmental change that is complex, contextual, and requires evidence-based reasoning. In this context, students need to develop high-level thinking skills, including critical, creative, collaborative, communicative, and reflective thinking skills in order to be able to understand the relationship between biological concepts, environmental phenomena, and rational alternative problem-solving (Asbari et al., 2024; Karim, 2020). However, biology learning in many classes still tends to emphasize mastery of factual information and memorization of concepts, so it does not fully provide space for students to test understanding, interpret learning experiences, and relate scientific concepts to real situations (Fransiska et al., 2021; Widyastuti, 2025). This condition shows a gap between the demands of biology learning that emphasize contextual reasoning and learning practices that are still limited to knowledge transmission.

One of the important skills that needs to be developed in biology learning is reflective thinking. Reflective thinking refers to an active and conscious process of evaluating experiences, interpreting information, connecting knowledge to contextual situations, and drawing logical conclusions or determining appropriate actions through systematic reasoning (Masatlıoğlu & Balaban, 2024; Titus & Muttungal, 2024). In science learning, this ability is crucial because students are not only asked to understand concepts but also to interpret phenomena, evaluate evidence, compare possible explanations, and make scientific decisions. In environmental change material, reflective thinking is increasingly important because students face problems such as pollution, ecosystem damage, climate change, biodiversity decline, and human behavior that affect environmental sustainability. The material requires students to understand causal relationships, critically assess information, and formulate solutions grounded in deep conceptual understanding (Pangestuti & Aloysius, 2025).

Based on on-the-ground observations, reflective thinking skills remained low, with an average achievement of 51%. By indicator, the reacting aspect was in the medium category at 57%, while the comparing aspect was 50% and the contemplating aspect was 45%, still in the low category. These findings indicate that students are relatively able to provide an initial response to a problem but still have difficulty comparing information, connecting experiences with concepts, and drawing deeper meanings from the learning process. Low achievement may be related to teacher-centered learning, limited research activities, a lack of space for reflective discussion, and limited student involvement in problem-solving that is close to real life (Nuraini et al., 2020). This condition aligns with research findings by Nuraini et al. (2020) and Saritepeci and Yildiz Durak (2024), which show that students often have difficulty analyzing information, connecting knowledge to new situations, and evaluating thought processes when learning has not provided an active and reflective learning experience. Sari et al. (2020) emphasize that the dominance of lecture methods causes students to tend to be passive in learning. Therefore, a learning model is needed that not only increases student participation but also facilitates deep, creative, and reflective thinking.

Deep learning can serve as a pedagogical foundation for more meaningful learning because it emphasizes students' involvement in understanding concepts in depth, awareness of the learning process, and building connections between knowledge and real-world contexts (Fullan et al., 2018; Sari & Arta, 2025). These works emphasize that deep learning encourages students to develop conceptual understanding, active engagement, and the ability to apply knowledge in new situations. In the context of biology learning, this approach is relevant because environmental change is not sufficiently understood as a collection of definitions or facts but needs to be studied as a systemic phenomenon involving interactions among biotic and abiotic components, human activity, and ecological impacts. Thus, Deep Learning can help students build a more complete

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understanding of environmental issues and encourage them to reflect on the scientific and social implications of the concepts studied. To make the deep learning process more structured, Deep Learning can be integrated with the Creative Problem-Solving model. The Creative Problem-Solving model provides a systematic sequence for understanding the problem, gathering facts, formulating the problem, generating ideas, choosing solutions, and designing the acceptance or implementation of solutions (Mitchell & Kowalik, 1989; Treffinger & Isaksen, 2005). These stages allow students to use divergent and convergent thinking processes in a balanced manner. At the divergent thinking stage, students are encouraged to generate various alternative ideas in response to environmental problems. In the convergent thinking stage, students assess the feasibility of solutions based on evidence, biological concepts, and rational considerations. This process aligns with reflective thinking abilities because students not only solve problems but also review reasons, compare alternatives, evaluate decisions, and reflect on the consequences of the chosen solution.

Conceptually, integrating Deep Learning and Creative Problem-Solving is seen as relevant for improving students' reflective thinking skills. Deep Learning provides direction for the formation of meaningful, conscious, and contextual understanding, while Creative Problem-Solving provides learning procedures that encourage students to identify problems, analyze information, develop alternative solutions, and evaluate decisions. The relationship between these two approaches aligns with the indicators of reflective thinking, namely reacting, comparing, and contemplating. In the reacting indicator, students respond to environmental change phenomena based on initial experience and information. In the comparing indicator, students compare facts, concepts, and alternative solutions. In the contemplating indicator, students draw meaning, evaluate the thought process, and formulate follow-ups based on scientific considerations. Thus, the relationship between learning variables and reflective thinking abilities is not assumed directly but is built through theoretical linkages among deep learning experiences, creative problem-solving, and reflection processes (Fullan et al., 2018).

Although various studies have highlighted the importance of reflective thinking skills and the use of active learning models in science education, empirical research on integrating Deep Learning approaches with the Creative Problem-Solving model for environmental change materials at the high school level remains limited. Previous research has generally treated reflective thinking as a learning outcome or positioned problem-solving as a strategy to improve learning outcomes, but few have systematically explained how deep learning experiences and the stages of Creative Problem-Solving contribute to students' reflective thinking indicators (Nuraini et al., 2020; Saritepeci & Yildiz Durak, 2024). Addressing these gaps, this study aims to analyze improvements in the reflective thinking skills of Grade X students on environmental change materials through the application of the Creative Problem-Solving model with Deep Learning and to measure the model's contribution to students' reflective thinking skills. This research is expected to make an empirical contribution to the development of biology learning that is more reflective, contextual, and scientifically oriented toward environmental problem solving.

METHODS

Research Design

This study employed a quantitative approach with a weak experimental design, specifically a one-group pre-test–post-test design involving three classes as replication groups to strengthen the findings and reduce potential bias. This design was used to examine changes in students' reflective thinking skills before and after implementing biology learning using the Creative Problem Solving with Deep Learning model. The research design followed the pattern O_1 X O_2, where O_1 represents the pre-test, X the learning intervention, and O_2 the post-test (Fraenkel & Wallen, 1990). The study was conducted with Grade 10 students at a public senior high school. As this design did not include

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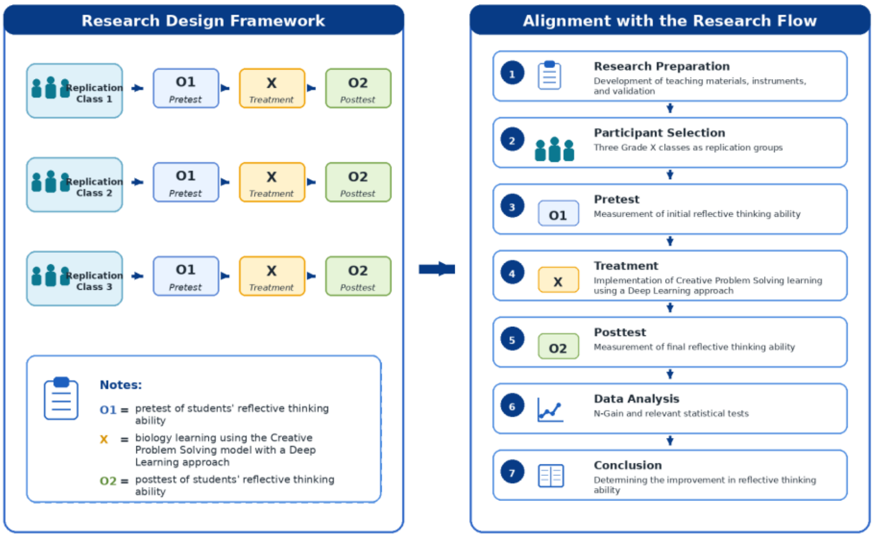
a control group, the interpretation of the findings focused on the improvement in N-gain scores as an indicator of changes in students' reflective thinking skills following the intervention.

Figure 1

Design and research flow.



(Fraenkel & Wallen, 1990)

Population and Samples

The population of this study comprised all Grade 10 students at a public senior high school, across eight classes with a total of 282 students. The sample was selected using purposive sampling and comprised three research classes (Class 1, n = 36; Class 2, n = 36; and Class 3, n = 36), yielding a total sample of 108 students. These three classes received the same learning intervention and served as replication groups to strengthen the consistency and reliability of the research findings. The classes were selected based on several criteria, including relatively homogeneous academic ability, high learning motivation, and readiness to engage in critical and reflective thinking, thereby facilitating the implementation of the learning innovation.

Instruments

The two instruments used include a reflective thinking ability test in the form of essay questions and an assessment scale to measure students' reflective aspects. The thinking ability test consists of 10 essay questions developed based on reflective thinking indicators that cover three main aspects: Reacting, Comparing, and Contemplating (Sari et al., 2020). Meanwhile, the reflective thinking scale consists of 20 statements. The goal is to find out how students' ability to respond when given environmental change material to the learning process is measured using a four-point Likert scale, which includes (strongly agree), (agree), (disagree), (strongly disagree). The instrument developed in this study underwent two validation stages: expert judgment and empirical validation. Expert validation was conducted by two experts, one a learning model design expert and one an educational evaluation and material expert, to assess the appropriateness of the instrument's content, readability, and construct. Furthermore, empirical validation was conducted through a product trial on 30 respondents outside the main sample. The trial data were statistically analyzed using Pearson's Product Moment correlation analysis for validity testing and the Cronbach's Alpha formula for reliability testing to ensure the instrument's consistency before being used in primary data collection. The validation results show that the instrument is suitable for use, with several revisions. The instrument grids used are presented in Table 1, while Table 2 below presents a reflective thinking scale grid.

Table 1
Reflective thinking test grid.

Reflective Thinking Indicators	Description	Question points
Reacting	Students' responses to problems and provide opinions based on learning experiences.	1, 4, 7
Comparing	Ability to compare information, connect and analyze concepts	2, 5, 8
Contemplating	Evaluate the thought process, draw conclusions, and determine solutions.	3, 6, 9, 10
	Quantity	10

Note: Adapted from (Alfina, 2024; Surbeck et al., 1991)

Table 2
Reflective thinking scale grid.

Reflective Thinking Indicators	Statement Type				Statement Number		Quantity
	Positive (+)	Value	Negative (-)	Value	Positive (Favourable)	Negative	
Reacting	SS	4	SS	1	1, 5, 7, 8, 9	2,3,4	8
	S	3	S	2			
	TS	2	TS	3			
	STS	1	STS	4			
Comparing	SS	4	SS	1	11	10,12	3
	S	3	S	2			
	TS	2	TS	3			
	STS	1	STS	4			
Contemplating	SS	4	SS	1	13, 15, 16, 17, 19,	6, 14, 18, 20	9
	S	3	S	2			
	TS	2	TS	3			
	STS	1	STS	4			
			Quantity				20

The instrument's empirical validity was tested through a trial with 35 students. The validity test results showed that 10 of 15 questions in the reflective thinking test met the validity criteria, while some items that did not meet the criteria were eliminated. Similarly, in the reflective thinking scale instrument, 20 out of 30 statements were declared valid, with 10 statements eliminated because they were not eligible. In addition, an analysis of the level of difficulty and differentiation in the essay test instrument was also carried out to analyze the level of difficulty and differentiation to ensure the quality of the question items in measuring students' reflective thinking skills. These findings show that most of the question items are empirically valid and appropriate for measuring students' reflective thinking skills. Reliability analysis using Cronbach's alpha yielded a coefficient of 0.797 for the reflective thinking test and 0.825 for the reflective thinking scale, both categorized as high reliability. This shows that the instrument has good internal consistency and produces stable measurement results, so it can be relied on to assess students' reflective thinking skills. Thus, the final instrument used in this study consisted of 10 essays and 20 scale statements to measure reflective thinking skills.

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Procedures

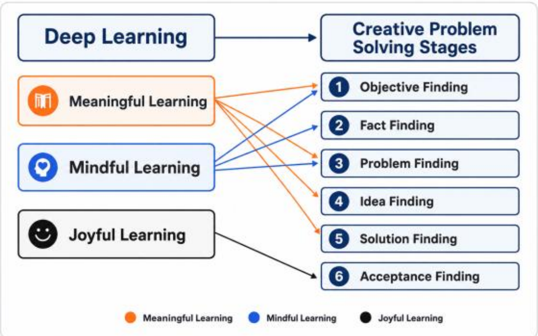
This study was conducted through three main stages: pre-test, treatment, and post-test. The treatment phase consisted of four learning meetings, each lasting three instructional periods (135 minutes), during which the Deep Learning approach integrated with the Creative Problem-Solving model was implemented in biology learning on environmental change materials. In the first stage, students were given a pre-test to measure their initial reflective thinking ability based on the indicators of reacting, comparing, and contemplating. This pre-test aimed to determine students' initial condition before treatment. In the second stage, treatment was carried out by applying the Deep Learning approach integrated with the Creative Problem-Solving model in learning biology on environmental change materials. The learning process was carried out in stages according to the syntax, namely objective finding, fact finding, problem finding, idea finding, solution finding, and acceptance finding.

During the objective-finding stage, students are guided to identify learning goals and phenomena related to environmental change. Then, in the fact-finding stage, they collect information through observation, discussion, and relevant resources. In the problem-finding stage, students develop problems based on the collected facts. Next, during the idea-finding stage, students creatively generate various alternative solutions through group discussions. In the solution-finding stage, they evaluate and select the most appropriate solution based on logical and scientific reasoning. Finally, in the acceptance-finding stage, students prepare an action plan and present their results of the problem-solving process. This sequence encourages in-depth research, comparison of different perspectives, and reflection on the reasoning process used to solve problems. Additionally, group discussions provide opportunities for idea exchange, argument testing, and re-evaluating understanding (Mukhoyaroh et al., 2025).

All stages are integrated with deep learning, which emphasizes meaningful learning (meaningful learning), conscious learning (mindful learning), and fun learning (joyful learning), so that students not only understand deep concepts but also relate knowledge to real-life contexts (Arif et al., 2025). During the learning process, students are actively involved in discussions, analysis of environmental phenomena, contextual problem solving, and reflection on the thought process carried out. In the final stage, students are given a post-test to measure their reflective thinking skills after participating in learning. The post-test results are then compared with the results of the pre-test to determine the improvement of students' reflective thinking skills and to analyze the influence of the Deep Learning approach with the Creative Problem Solving on students' reflective thinking ability. The use of a pre-test post-test comparison design allows researchers to identify changes in students' abilities in a more measurable manner after being given learning interventions and to clarify the relationship between the Deep Learning Approach and the Creative Problem-Solving Model presented on the chart as follows in Figure 2.

Figure 2

The influence of the deep learning approach and the creative problem-solving model.



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Data Collection and Analysis

In this study, the analysis focused on improving reflective thinking; the data were analyzed using N-Gain to determine the improvement in reflective thinking skills, as shown in Table 3. Prior to hypothesis testing, a preliminary analysis was conducted to verify whether the data met the assumptions for parametric statistical analysis. Data normality was assessed using the Kolmogorov–Smirnov test, while the homogeneity of variance was evaluated using Levene's test. Data were considered normally distributed and homogeneous if the significance value (p) exceeded 0.05 (Usmadi, 2020). After confirming that the data met the assumptions of normality and homogeneity, hypothesis testing was conducted using a paired-sample t-test to compare students' reflective thinking scores before (pre-test) and after (post-test) the implementation of the Deep Learning approach integrated with the Creative Problem-Solving model. The paired-sample t-test was selected because the pre-test and post-test scores were obtained from the same participants. A statistically significant difference ($p < 0.05$) indicated that the intervention produced a significant improvement in students' reflective thinking skills. Furthermore, Pearson's product-moment correlation analysis was conducted to examine the relationship between the implementation of the learning approach and students' reflective thinking skills. The contribution of the learning approach was then estimated using the coefficient of determination (r^2), which was obtained by squaring the Pearson correlation coefficient ($r \times r$). The resulting coefficient of determination (r^2) represents the proportion of variance in students' reflective thinking skills explained by the Pearson correlation between the learning approach and reflective thinking skills.

Table 3

Results of data homogeneity and normality test.

Tests of Normality (*Kolmogorov-Smirnov)*			**Test of Homogeneity of Variance (Levene's)**		
Class	Statistic	Sig.	Statistic		Sig.
1	0.101	0.111	Based on Mean	4.103	0.124
2	0.117	0.120	Based on Median	3.595	0.139
3	0.142	0.132	Based on Median and Width	3.595	0.156
			Based on trimmed mean	3.731	0.162

Based on Table 3, the results of the prerequisite test show that the N-Gain data for reflective thinking ability meet the assumptions of normality and homogeneity. The normality test using the Kolmogorov–Smirnov test yielded a significance value of 0.111 in class 1, 0.120 in class 2, and 0.132 in class 3, all of which were greater than 0.05, indicating that the data were normally distributed. Furthermore, the homogeneity test using Levene's Test (Based on Mean) obtained a statistical value of 4.103 with a significance value of 0.124 ($p > 0.05$ (α)), indicating that the data variance in the three classes was homogeneous. Thus, the data met the prerequisites for further statistical analysis.

Table 4

Scores according to N-gain.

Yes	**Limitations**	**Categories**
1.	$g>0.70$	Height
2.	$0.31 \leq g \leq 0.70$	Medium
3.	$g < 0.30$	Low

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RESULTS AND DISCUSSION 6

The results of this study show that applying the Deep Learning approach integrated with the Creative Problem-Solving model is effective in improving students' reflective thinking skills. This improvement occurs because the learning process is designed to encourage learners to be actively involved in finding problems, analyzing facts, formulating solutions, and reflecting on problem-solving results. The recapitulation of the results of the reflective thinking ability test for students can be seen in Table 5.

Table 5

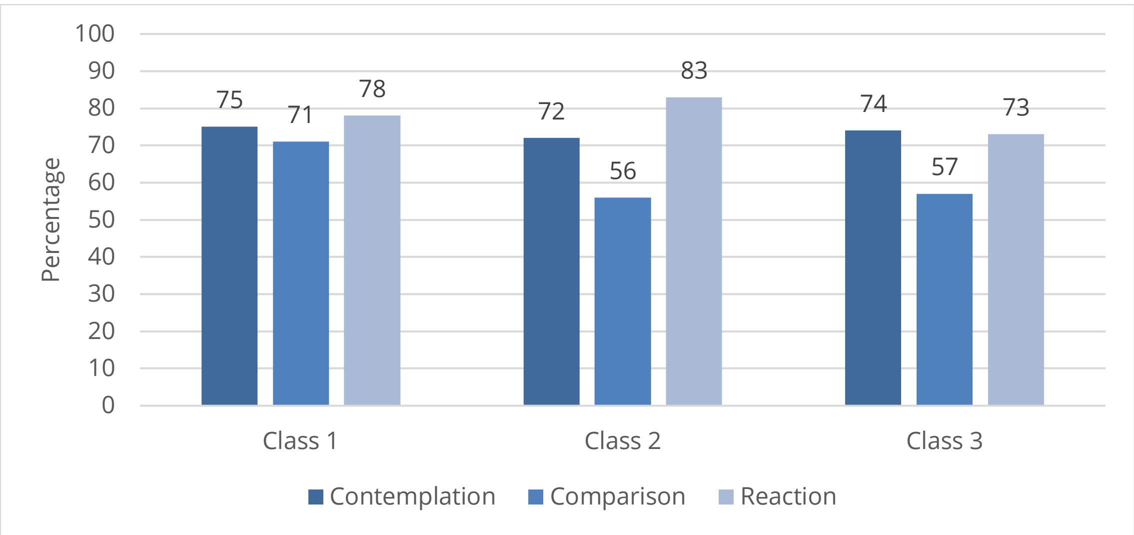
Results of N-gain improvement of reflective thinking ability in classes 1, 2, and 3.

Classes	Average Pre-test	Post-test Average	Average N-Gain	Categories
1	58,65	92,60	0,83	Height
2	63,39	91,24	0,77	Height
3	61,03	91,23	0,77	Height

Based on Table 5, all research classes experienced an increase in reflective thinking skills in the high category. In the reflective thinking ability test, the first research class obtained the highest N-Gain value of 0.83, followed by the second research class of 0.77 and the third research class of 0.77. These findings show that deep learning integrated with the Creative Problem-Solving model not only improves students' ability to analyze and solve biological problems reflectively, but also strengthens awareness of the learning process. The increase in the reflective thinking test represents the development of cognitive aspects in students' reflective thinking, while the increase in the reflective thinking scale shows the development of students' reflective thinking in evaluating learning experiences. This confirms that learning that is designed in depth is able to improve the ability to think reflectively gradually; the improvement of reflective thinking skills of each indicator in the research class can be seen in Figure 3 as follows:

Figure 3

N-gain results per reflective thinking ability indicator.



Based on Figure 3, reflective thinking ability results vary across indicators in the three research classes, influenced by the learning process, student characteristics, and classroom

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environmental conditions. For example, the Reaction indicator tends to experience greater improvements because these abilities are related to responding to questions, conveying simple opinions, and providing initial responses to given problems. The indicator Comparing experienced moderate improvement because students were required to compare information, relate the material to previous experience, and assess several alternative solutions. This ability requires a sufficient understanding of the material and the habit of discussing, so not all students can master it in a short time. However, group work activities and discussions during learning help students exchange opinions so that this indicator continues to improve. Meanwhile, the contemplating indicator tends to decrease because learners must be able to evaluate their own thought processes, conclude learning, and reflect on the solutions chosen. In fact, many students are still not used to deep reflection and are more focused on completing tasks than on reviewing their thought processes; differences in academic ability between students also affect the results of each indicator. Thus, students solving problems with reflective thinking skills through regular completion of steps will train them to develop skills and relate experiences to the learning process (Suhaji, 2020). In addition to the improvement analysis, hypothesis testing was carried out to determine the significance of the effect of treatment on students' reflective thinking skills. The improvement of reflective thinking skills can be seen from the students' answers presented as follows:

Table 6

Categories of students' answers to the reflective thinking ability test.

Students' answers to reflective thinking skills test High Category		
Reacting (Class 1)	Pada Mei 2024, Sumatera Barat berduka akibat banjir lahar dingin yang melanda kawasan di sekitar Gunung Marapi, seperti di Agam dan Tanah Datar. Meskipun pemicu utamanya adalah material vulkanik dan hujan lebat, data menunjukkan adanya kerusakan vegetasi di lereng gunung akibat pembukaan lahan. Warga yang awalnya menganggap pembukaan hutan untuk kebun adalah hal biasa, kini harus kehilangan rumah dan anggota keluarga. Berdasarkan peristiwa di atas, analisislah bagaimana seharusnya Rekasi mahluk hidup terhadap perubahan tutupan lahan di hulu dapat mengubah drastis keseimbangan ekosistem di hilir. apakah Anda akan tetap mempertahankan asumsi bahwa "menebang pohon di gunung tidak akan berpengaruh pada desa di bawah"? Berikan alasan kritis Anda. Asumsi tersebut sudah pasti salah, karena pohon berkontribusi penting terhadap alam. Pohon dapat menguatkan struktur tanah yang dapat mencegah terjadi longsor yang membahayakan pemukiman, pohon juga membantu tanah dalam proses penyerapan air karena tanah memiliki kapasitas terbatas dalam penyerapan air, pohon juga mempengaruhi presipitasi disuatu daerah karna di daerah yang jauh dari sumber air memiliki peran 60-75% dalam total oroses penguapan air yang ada di daerah tersebut sedangkan jika deforestasi terjadi maka intensitas evaporasi akan berkurang yang menyebabkan intensitas presipitasi akan berkurang yang dapat menyebabkan kekeringan	
Reacting (Class 2)	Pada Mei 2024, Sumatera Barat berduka akibat banjir lahar dingin yang melanda kawasan di sekitar Gunung Marapi, seperti di Agam dan Tanah Datar. Meskipun pemicu utamanya adalah material vulkanik dan hujan lebat, data menunjukkan adanya kerusakan vegetasi di lereng gunung akibat pembukaan lahan. Warga yang awalnya menganggap pembukaan hutan untuk kebun adalah hal biasa, kini harus kehilangan rumah dan anggota keluarga. Berdasarkan peristiwa di atas, analisislah bagaimana seharusnya Rekasi mahluk hidup terhadap perubahan tutupan lahan di hulu dapat mengubah drastis keseimbangan ekosistem di hilir. apakah Anda akan tetap mempertahankan asumsi bahwa "menebang pohon di gunung tidak akan berpengaruh pada desa di bawah"? Berikan alasan kritis Anda. tentu saja saya tidak akan mempertahankan asumsi tersebut. mau bagaimana pun hulu dan hilir sebenarnya adalah satu kesatuan, jika kita melakukan penebangan massal dan liar, maka apa yang akan terjadi pada desa yang ada di bagian bawah.. peralihan hutan ke kebun sama saja seperti menghilangkan pertahanan utama bagi desa yang ada di bawah gunung tersebut, dengan mengubah hutan menjadi kebun, akar pohon serta tanah yang tadinya berfungsi untuk menampung air hujan, berkurang kerapatannya, sehingga bencana banjir lahar dingin, air atau longsor akan lebih sering terjadi.	Score 3: Learners gave a strong and honest emotional response to the tragedy. They show a high level of self-awareness that upstream actions have a direct impact on downstream, and they firmly reject old false assumptions for reasons that touch on the human side.
Reacting (Class 3)	Pada Mei 2024, Sumatera Barat berduka akibat banjir lahar dingin yang melanda kawasan di sekitar Gunung Marapi, seperti di Agam dan Tanah Datar. Meskipun pemicu utamanya adalah material vulkanik dan hujan lebat, data menunjukkan adanya kerusakan vegetasi di lereng gunung akibat pembukaan lahan. Warga yang awalnya menganggap pembukaan hutan untuk kebun adalah hal biasa, kini harus kehilangan rumah dan anggota keluarga. Berdasarkan peristiwa di atas, analisislah bagaimana seharusnya Rekasi mahluk hidup terhadap perubahan tutupan lahan di hulu dapat mengubah drastis keseimbangan ekosistem di hilir. apakah Anda akan tetap mempertahankan asumsi bahwa "menebang pohon di gunung tidak akan berpengaruh pada desa di bawah"? Berikan alasan kritis Anda. Saya tidak akan mempertahankan diri pernyataan tersebut dikarenakan pohon-pohon yang hidup, apalagi dalam jangka waktu yang tidak sebentar pasti memiliki perakaran yang kuat dan membentuk ekosistem sendiri. Sehingga dari kedua argumen tersebut, dapat saya pastikan pentingnya pohon di pegunungan bagi desa-desa di bawahnya, sebagai pelindung, pemasok makanan dan penjaga ekosistem alami primer di sekitar masyarakat. Kesimpulannya, saya tidak akan mempertahankan hal tersebut karena untuk membentuk suatu ekosistem yang seimbang memerlukan beberapa komponen penting seperti ruang terbuka hijau dengan tingkat 20-30%.	

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<table>
<tr><th colspan="3">Students' answers to reflective thinking skills test
High Category</th></tr>
<tr><td>Comparing
(Class 1)</td><td>A
Sumber: https://jatimnow.com/baca-74398-hutan-mangrove-di-pesisir-timur-sidoarjo-rusak-parah-butuh-penanganan-pemkab

B
Sumber: https://penjagalaut.org/alih-fungsi-lahan-merusak-mangrove-kita/

Area A lebih aman karena Desa dengan hutan mangrove lebat jauh lebih aman. Mangrove berfungsi sebagai benteng alami yang meredam energi ombak serta air laut yang tertahan oleh akar dan tanah mangrove tidak langsung masuk ke pemukiman, menjaga air tanah tetap tawar dan tidak mencemari sumber air bersih warga sekitar daerah nah kalau area b tidak aman karena hilangnya benteng alami akan membuat tercemarnya sumber air bersih (tawar) warga dimana tercampur dengan air asin, kita tau kalo air asin itu tidak layak konsumsi karena salinitasnya yang terlalu tinggi dan bisa memicu hipertensi. Walau segi ekonomi bisa diuntungkan namun resiko yang lainnya sangat tidak sepadan dari segi kesehatan, dll</td><td>Score 3: Students were able to compare the role of mangroves appropriately, link environmental damage to long-term health risks, and provide in-depth reflection on personal responsibility.</td></tr>
<tr><td>Comparing
(Class 2)</td><td>Sungai Citarum sempat dijuluki sungai terkotor di dunia karena limbah pabrik. Namun, selokan di depan rumah kita juga sering hitam dan berbau karena sisa cucian (detergen) dan minyak goreng sisa yang kita buang langsung ke sana. Bandingkan dampak limbah industri yang besar dengan limbah domestik (rumah tangga). Manakah yang menurut Anda lebih sulit diatasi jika masyarakatnya belum memiliki kesadaran kritis? Mengapa tanggung jawab memperbaiki lingkungan harus dimulai dari selokan depan rumah kita sendiri? *

Keduanya akan sulit diatasi apabila belum memiliki kesadaran kritis. Jika kesadaran kritis sudah ada di tiap masyarakat maka hal yang perlu diatasi pertama ialah selokan di depan rumah karena tanggung jawab akan kebersihan di lingkungan sekitar akan berdampak besar bagi kesehatan masyarakat juga. Selain alasan ini juga, bertanggung jawab akan sektor besar seperti industri tidak akan terjadi apabila sektor kecil seperti keluarga belum terlaksana dengan baik.

Maka dari itu, kebiasaan dalam menjaga pasokan air bersih dan sanitasi perlu dilakukan di tiap rumah-rumah untuk membentuk suatu gaya hidup, menciptakan ruang yang sehat dan nyaman.</td><td rowspan="2">Score 3: Students provided a sharp comparison between industrial and domestic waste, and were able to conclude that domestic waste is more difficult to overcome due to the massive number of (personal) perpetrators. The answer shows an awareness that major change must start from individual actions (the gutter of the house).</td></tr>
<tr><td>Comparing
(Class 3)</td><td>Sungai Citarum sempat dijuluki sungai terkotor di dunia karena limbah pabrik. Namun, selokan di depan rumah kita juga sering hitam dan berbau karena sisa cucian (detergen) dan minyak goreng sisa yang kita buang langsung ke sana. Bandingkan dampak limbah industri yang besar dengan limbah domestik (rumah tangga). Manakah yang menurut Anda lebih sulit diatasi jika masyarakatnya belum memiliki kesadaran kritis? Mengapa tanggung jawab memperbaiki lingkungan harus dimulai dari selokan depan rumah kita sendiri? *

diantara kedua masalah tersebut, menurut saya limbah di depan selokan rumah orang-orang akan lebih susah di hilangkan jika tidak ada kesadaran diri dari setiap individu. meskipun sungai citarum memiliki skala yang besar permasalahan nya, namun, jika di pikirkan, sebenarnya limbah tersebut berasal dari air-air selokan masyarakat yang mengalir kesana. jadi, percuma kita langsung menuntaskan masalah terbesarnya jika kita tidak mencabut akar dari permasalahan tersebut terlebih dahulu. karena, dengan adanya kesadaran dari hal termudah seperti menjaga selokan rumah sendiri, akan berdampak pada sikap kita menjaga sungai citarum juga.</td></tr>
<tr><td>Contemplating
(Class 1)</td><td>Inovasi solusi berkelanjutan memerlukan lebih dari sekadar teknologi tetap juga membutuhkan etika. Program "Sekolah Bebas Plastik" seringkali gagal karena siswa hanya patuh jika diawasi. *

Apakah Anda menjaga lingkungan karena aturan sekolah atau karena Anda menyadari bahwa merusak alam adalah bentuk ketidakadilan terhadap makhluk hidup lain? Rancanglah satu aksi kreatif yang tidak hanya memindahkan sampah, tapi mengubah pola pikir teman-teman Anda di Bandar Lampung untuk lebih peduli pada lingkungan. Apa alasan mendasar mengapa solusi Anda disebut berkelanjutan?

Saya menjaga lingkungan karena menyadari bahwa merusak alam adalah bentuk ketidakadilan terhadap makhluk lain.

Salah satu aksi kreatif yang saya miliki ialah membuat gudang kompos di tiap sudut sekolah yang nantinya akan dijual atau digunakan untuk pupuk tanaman sekitar lewat daun dan dahan yang berjatuhan di lingkungan sekolah, selain itu saya akan membuat suatu ekstrakurikuler yang berisi inovasi dan pengembangan daur ulang sampah untuk memberikan wadah bagi para pemuda menjadi agen perubahan secara terus menerus dari generasi ke generasi.</td><td rowspan="3">Score 3: Students provide honest, personal identification of actions, are able to construct a "natural rebuke" that addresses the ethical dimension, and formulate a very specific (not just theoretical) commitment to behavior change.</td></tr>
<tr><td>Contemplating
(Class 2)</td><td>Inovasi solusi berkelanjutan memerlukan lebih dari sekadar teknologi tetap juga membutuhkan etika. Program "Sekolah Bebas Plastik" seringkali gagal karena siswa hanya patuh jika diawasi.

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saya menjaga lingkungan karena faktor keduanya, karena saya sadar bahwa semakin rusak lingkungan karena sampah maka semakin rusak juga kesehatan dan kenyamanan kita, perusakan lingkungan ini akan menjadi efek berantai yang berujung pada manusia juga akibatnya. bisa membuat seperti prinsip reuse yaitu menggunakan ulang sampah terutama plastik jadi eco brick atau produk lain yang berguna seperti kerajinan miniatur PLTA yang model kincir itu, karena selain menarik secara estetika juga mengurangi penumpukan sampah</td></tr>
<tr><td>Contemplating
(Class 3)</td><td>Inovasi solusi berkelanjutan memerlukan lebih dari sekadar teknologi tetap juga membutuhkan etika. Program "Sekolah Bebas Plastik" seringkali gagal karena siswa hanya patuh jika diawasi. *

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menurut saya, menjaga lingkungan harusnya datang dari kesadaran diri sendiri, bukan hanya karena aturan. kita harus sadar bahwa setiap tindakan kita berdampak ke makhluk hidup lain, lingkungan, dll di bumi.

untuk idenyaa, saya punya satu ide kreatif, yaituu, "sampah jadi cerita". nah, nanti saya akan buat lomba membuat karya seni dari sampah yang ada di sekolah. siswa-siswa bisa ngebuat apa aja, kayak patung, lukisan, atau puisi, dari sampah yang mereka kumpulkan.

ada pertunjukan di tempat limbah-limbah yang udah parah buat nunjukin betapa pentingnya jaga lingkungan. dengan ini, kita tidak cuma memindahkan dan mengolah sampah, tetapi juga mengubah pola pikir kita. saya akan ajak siswa siswi lain untuk berpikir kreatif tentang sampah, sadar akan dampaknya, dan apa solusinya. jadi kita semua bisa samacsama belajar dan memahami betapa pentingnya menjaga lingkungan sehingga hal tersebut bisa berlanjut.</td></tr>
</table>

Improvements in each indicator across the three research classes were influenced by the implemented learning process and classroom learning environment, both of which play an important role in promoting students' reflective thinking and metacognitive development (Carney-Anderson, 2026; Titus & Muttungal, 2024). High-category students demonstrated stronger performance on the Reacting indicator by providing more elaborate responses and relating environmental problems to their broader impacts, consistent with the initial reflective response described by Surbeck et al. (1991). On the Comparing indicator, they effectively integrated prior knowledge with newly acquired information and justified their proposed solutions, reflecting the comparative elaboration stage of reflective thinking (Rodgers, 2002; Surbeck et al., 1991). Furthermore, students in the high category achieved better performance on the Contemplating indicator by evaluating their reasoning processes and proposing well-considered solutions, whereas students in the medium category tended to focus primarily on the final outcome rather than critically reviewing their reasoning process (Rodgers, 2002; Yang et al., 2026). Overall, these findings indicate progressive development of reflective thinking across all indicators, although the depth of reflection varied among students (Carney-Anderson, 2026; Titus & Muttungal, 2024).

The results of the analysis of improvements in reflective thinking skills vary across indicators. The Reacting indicator tends to show greater improvement because these abilities involve responding to questions, expressing simple opinions, and providing initial responses to given problems. The Comparing indicator tends to increase less because students are required to compare information, relate material to previous experience, and assess several alternative solutions. This ability requires a solid understanding of the material and a habit of discussion, so not all students can master it in a short time. However, group work and discussions during learning help students exchange opinions, so this indicator continues to increase (Antonio, 2020; Yaacob et al., 2021). Meanwhile, the Contemplating indicator increases moderately because students must be able to evaluate their own thought process, conclude learning, and reflect on the solutions chosen. In fact, many students are still not used to deep reflection and are more focused on completing tasks rather than reviewing their thinking process; differences in academic abilities between students also affect the results of each indicator.

The Effect of the Deep Learning Approach with the Creative Problem-Solving model on Students' Reflective Thinking Skills

Hypothesis testing was conducted to determine whether implementing a Deep Learning approach integrated with the Creative Problem-Solving model had a significant effect on students' reflective thinking skills. Reflective thinking skills were measured using two complementary instruments: a reflective thinking essay test and a reflective thinking scale. To obtain a comprehensive measure of students' reflective thinking skills, statistical analysis was performed using a composite score derived from both instruments; therefore, the results presented in Table 7 represent the hypothesis testing based on the composite reflective thinking score.

Table 7

Results of the paired sample t-test of students' reflective thinking scores.

Paired Sample t-Test							
Research Class	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference	t	df	Sig. (2-Tailed)	Cohen's d
1	59.00 ± 8.65	93.00 ± 4.18	34.00	-30.059	35	<.001	5.010
2	63.75 ± 8.31	91.64 ± 4.35	27.89	-30.059	35	<.001	4.656
3	61.33 ± 6.22	91.61 ± 4.12	30.28	-27.097	35	<.001	4.516

Based on the results of the paired-samples t-test presented in Table 7, statistically significant differences were found between the pre-test and post-test scores of students' reflective thinking skills in all three research classes ($p < 0.001$). In Research Class I, the mean score increased from

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59.00 ± 8.65 to 93.00 ± 4.18 ($t (35) = -30.059, p < 0.001$). Similarly, Research Class II increased from 63.75 ± 8.31 to 91.64 ± 4.35 ($t (35) = -27.938, p < 0.001$), while Research Class III improved from 61.33 ± 6.22 to 91.61 ± 4.12 ($t (35) = -27.097, p < 0.001$). These findings indicate that students' reflective thinking skills improved significantly after implementing the Deep Learning approach integrated with the Creative Problem-Solving model. Furthermore, Cohen's d values of 5.010, 4.656, and 4.516 for Research Classes I, II, and III, respectively, indicate very large effect sizes, demonstrating that the intervention produced a substantial educational impact. These statistical findings are further supported by the high N-Gain values obtained across the three research classes, indicating that the observed improvement was not only statistically significant but also reflected meaningful learning gains.

The influence of this approach stems from Deep Learning with the Creative Problem-Solving model. It emphasizes students' active involvement in building their understanding. In addition, students are directed to identify real problems, analyze the information obtained, evaluate various alternative solutions, and reflect on the decisions taken. A strong literacy foundation encourages reflective thinking because it allows students to understand information in depth before conducting the analysis and evaluation process. These conditions align with Bardi et al. (2025), which shows that literacy is not only the ability to write and read but also the ability to reflect on information in the learning process. Students in the superior class generally have better academic literacy and communication skills than those in regular classes. This ability makes it easier for them to understand problems, process information, and present the results of analysis systematically. This process encourages students to organize their own knowledge, develop high-level thinking skills, and build learning independence. In line with the submissions by Fullan et al. (2018), the approach of Deep Learning is oriented toward the development of in-depth conceptual understanding through the active involvement of learners in the learning experience. In addition, Treffinger and Isaksen (2005) state that Creative Problem Solving is a learning model designed to help students solve problems creatively through divergent and convergent processes. These findings align with Dewey's (1909) conception of reflective thinking as an active, persistent, and careful process of examining experiences and beliefs to reach reasoned judgments, which Rodgers (2002) further described as a systematic process of meaning making through reflection. Thus, the learning process that provides space for reflection and active involvement is able to improve the ability to think at a higher level, such as reflective thinking (Kember, 1999). In this study, students not only passively receive information but are actively involved in finding, evaluating, and reflecting on solutions to problem-solving related to environmental change. Thus, integrating the two provides ample space for students to optimally develop reflective thinking skills. This study also aims to see how much the application of the approach contributes to Deep Learning with the Creative Problem-Solving model in influencing the ability to think reflectively. The results of the analysis are presented in the following description, including:

The Contribution of the Deep Learning Approach with the Creative Problem-Solving model to Students' Reflective Thinking Skills

This research was also carried out to determine the large contribution of the Deep Learning approach with the Creative Problem-Solving model to students' reflective thinking ability. The results of the contribution analysis obtained in this study are presented in the following description.

Using the coefficient of determination (r^2) reported in Table 8, the contribution of the Deep Learning approach integrated with the Creative Problem-Solving model to students' reflective thinking skills was estimated by squaring the Pearson correlation coefficient (r). The results showed that the coefficient of determination was 22.0% for Research Class 1, 12.2% for Research Class 2, and 53.0% for Research Class 3. These findings indicate that the learning approach contributed positively to improving students' reflective thinking skills, although the magnitude of the contribution differed across the three research classes. The highest contribution was observed

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in Research Class 3, whereas the remaining variance in reflective thinking skills may be attributed to other factors not examined in this study. According to Mitchell and Kowalik (1989), the Creative Problem-Solving model is designed to develop creative problem-solving skills through structured thinking stages. This finding supports the research results that when students are faced with learning situations that demand in-depth analysis and evaluation, the reflection process develops more optimally (Inriani et al., 2021).

Table 8

Contribution of the deep learning approach integrated with the creative problem-solving model based on the squared Pearson correlation coefficient.

Class	Pearson Correlation (r)	Coefficient of Determination (r^2)	Contribution (%)
Class 1	0.568	0.220	22.0
Class 2	0.340	0.122	12.2
Class 3	0.440	0.530	53.0

Using the coefficient of determination (r^2) reported in Table 8, the contribution of the Deep Learning approach integrated with the Creative Problem-Solving model to students' reflective thinking skills was estimated by squaring the Pearson correlation coefficient (r). The results showed that the coefficient of determination was 22.0% for Research Class 1, 12.2% for Research Class 2, and 53.0% for Research Class 3. These findings indicate that the learning approach contributed positively to improving students' reflective thinking skills, although the magnitude of the contribution differed across the three research classes. The highest contribution was observed in Research Class 3, whereas the remaining variance in reflective thinking skills may be attributed to other factors not examined in this study. According to Mitchell and Kowalik (1989), the Creative Problem-Solving model is designed to develop creative problem-solving skills through structured thinking stages. This finding supports the research results that when students are faced with learning situations that demand in-depth analysis and evaluation, the reflection process develops more optimally (Inriani et al., 2021).

This contribution also has practical implications for learning, as teachers can use the Deep Learning approach alongside the Creative Problem-Solving model to increase student involvement while practicing reflective thinking skills in a structured manner. In addition, the contribution to each indicator shows that this approach is more effective in developing initial abilities, such as reacting, and gradually improves more complex abilities, such as comparing and contemplating. The advantage of integrating these two approaches lies in its ability to combine meaningful learning with a systematic problem-solving process, thereby not only improving conceptual understanding but also forming a reflective mindset in a sustainable manner. However, its effectiveness is still influenced by the consistency of learning implementation and students' readiness to engage in the learning process, which requires activity and deep thinking.

Based on the description above, the application of the Deep Learning approach integrated with the Creative Problem-Solving model has proven influential and has made a positive contribution to the reflective thinking ability of class X students, especially in learning biology materials on environmental change. These findings show that the more effectively meaningful, conscious, and fun learning is applied, with the creative problem-solving stage, the more it encourages students' ability to reflect on learning experiences, analyze problems, and evaluate their thinking process to develop further. These findings are in line with research Zahwa (2024), which shows that the application of innovative learning approaches is able to improve students' reflective thinking skills through active involvement in the learning process. Research results by Sari et al. (2020) show that Creative Problem Solving can encourage students to think more

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reflectively through structured problem-solving activities. The results of this study suggest that efforts to improve students' reflective thinking skills are not enough to convey biological concepts theoretically; they need to be supported by a learning process that provides space for students to explore ideas, reflect on learning experiences, and formulate systematic solutions to the problems they face.

CONCLUSION

The findings of this study indicate that students' reflective thinking skills improved significantly after participating in biology learning through the Deep Learning approach integrated with the Creative Problem-Solving model, as demonstrated by the paired-sample t-test results. Descriptive analysis also showed high N-Gain scores across all three research classes, indicating substantial improvement in students' reflective thinking abilities. Furthermore, the coefficient of determination (r^2) suggested that the learning approach contributed positively to students' reflective thinking skills, although the magnitude of the contribution varied among the three research classes. These findings suggest that integrating the Deep Learning approach with the Creative Problem-Solving model can serve as an effective instructional strategy to foster deeper, more critical, and more reflective thinking in biology learning, particularly on environmental change topics.

Nevertheless, the findings should be interpreted with caution because this study employed a one-group pre-test post-test design without a control group. Therefore, the observed improvements cannot be attributed exclusively to the intervention, as other factors, such as maturation, prior learning experiences, or external influences, may also have affected students' reflective thinking development. In addition, the use of purposive sampling and participants from a single school limits the generalizability of the findings. Future studies are recommended to employ more rigorous experimental or quasi-experimental designs involving control groups, larger and more diverse samples, and additional variables that may influence reflective thinking skills to provide stronger empirical evidence regarding the effectiveness of the Deep Learning approach integrated with the Creative Problem-Solving model.

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